NF07226US

ZOOM LENS SYSTEM

This application claims the benefit of Japanese Patent applications No. 2002-292827 filed October 4, 2002 and No. 2003-324679 filed September 17, 2003 which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a zoom lens system having a vibration reduction correction mechanism suitable for single lens reflex cameras and electronic still cameras, in particular, to a large aperture internal focusing telephoto zoom lens system.

Related Background Art

Zoom lens systems having a vibration reduction correction mechanism with the f-number of 5.8 or more able to be used for single lens reflex cameras and electronic still cameras have been proposed in Japanese Patent Application Laid-Open No. 10-90599 (page 5, Fig. 7).

However, in the above-disclosed example, the f-number (FNO) in the telephoto end state is very dark having from 5.85 to 8.27, so a fast zoom lens system having the f-number of 4 or less has been demanded.

SUMMARY OF THE INVENTION

The present invention is made in view of the aforementioned problems and has an object to provide a large aperture, internal focusing, telephoto zoom lens system having the FNO of about 4 or less capable of being used as a vibration reduction correction lens with keeping superior optical performance.

According to one aspect of the present invention, a zoom lens system consists of, in order from an object, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, and a fourth lens group having positive refractive power. Zooming is carried out by moving the second lens group and the third lens group along the optical axis. The first lens group consists of, in order from the object, a front lens group of the first lens group having positive refractive power, a middle lens group of the first lens group having negative refractive power, and a rear lens group of the first lens group having positive refractive power. In the fourth lens group, there are three lens portions with refractive power that are, in order from the object, a front lens group of the fourth lens group having positive refractive power, a middle lens group of the fourth lens group having negative refractive power, and a rear lens group of the fourth

lens group having positive refractive power. The front lens group of the first lens group includes two positive lens elements and a negative lens element. The middle lens group of the first lens group includes a positive element and a negative lens element. The rear lens group of the first lens group includes a positive lens element. Focusing to a close object is carried out by moving the middle lens group of the first lens group along the optical axis. The front lens group of the fourth lens group includes a positive element and a negative lens element. The middle lens group of the fourth lens group includes a positive element and two negative lens elements. The rear lens group of the fourth lens group includes a positive lens element and a negative lens element. Imaging position is varied by shifting the middle lens group of the fourth lens group perpendicular to the optical axis. The following conditional expression is satisfied:

$$2.5 < |(F1f \times F1r234t)/(F1m \times \Phi1)| < 5.0$$

where $\Phi1$ denotes the maximum effective diameter of the first lens group, F1f denotes the focal length of the front lens group of the first lens group, F1m denotes the focal length of the middle lens group of the first lens group, F1r234t denotes the combined focal length of the rear lens group of the first lens group, the second lens group, the third lens group,

and the fourth lens group in the telephoto end state.

In one preferred embodiment of the present invention, the following conditional expressions are preferably satisfied:

$$2.5 < |(F1f \times F4)/(F1mr23t \times \Phi 1)| < 5.0$$

$$2.5 < |(F1 \times F4)/(F23t \times \Phi 1)| < 5.0$$

$$2.5 < |(F1f \times F1r \times F4)/(F1m \times F23t \times \Phi 1)| < 5.0$$

$$0.7 < |(F4 \times F4m)/(F4f \times F4r)| < 1.3$$

where F1 denotes the focal length of the first lens group, F23t denotes the combined focal length of the second lens group and the third lens group in the telephoto end state, F4 denotes the focal length of the fourth lens group, F1r denotes the focal length of the rear lens group of the first lens group, F1mr23t denotes the combined focal length of the middle lens group of the first lens group, the rear lens group of the first lens group, the second lens group and the third lens group in the telephoto end state, F4f denotes the focal length of the front lens group of the fourth lens group, F4m denotes the focal length of the middle lens group of the fourth lens group, and F4r denotes the focal length of the rear lens group of the fourth lens group.

In one preferred embodiment of the present invention, the following conditional expressions are preferably satisfied:

$$0.025 < |(Ft \times \Phi 4f)/(F4 \times \Phi 1 \times \Phi 4m)| < 0.045$$

$$0.025 < |(F1 \times \Phi 4f)/(F23t \times \Phi 1 \times \Phi 4m)| < 0.045$$

$$0.020 < |(F1f \times \Phi 1r)/(F1m \times \Phi 1 \times \Phi 4m)| < 0.070$$

$$0.025 < |(F1r \times \Phi 4f)/(F23t \times \Phi 1r \times \Phi 4m)| < 0.045$$

where Ft denotes the focal length of the zoom lens system in the telephoto end state, Φ1r denotes the maximum effective diameter of the rear lens group of the first lens group G1r, Φ4f denotes the maximum effective diameter of the front lens group of the fourth lens group G4f, and Φ4m denotes the maximum effective diameter of the middle lens group of the fourth lens group G4m.

In one preferred embodiment of the present invention, the following conditional expression is preferably satisfied:

$$0.0031 < 1/(Nd1r \times F1r) < 0.0039$$

where Nd1r denotes average refractive index of the lens elements in the rear lens group of the first lens group at d-line.

In one preferred embodiment of the present invention, the most object side lens in the front lens group of the first lens group is a negative meniscus lens having a convex surface facing to the object, and the following conditional expression is preferably satisfied:

$$-0.0060 < 1/(NdL11 \times FL11) < -0.00050$$

where FL11 and NdL11 denote the focal length and refractive index at d-line of the negative meniscus

lens, respectively.

In one preferred embodiment of the present invention, the front lens group of the fourth lens group consists of two positive lens elements and a negative lens element, and the rear lens group of the fourth lens group consists of two positive lens elements and a negative lens element.

In one preferred embodiment of the present invention, a field stop is arranged between the front lens group of the fourth lens group and the middle lens group of the fourth lens group.

Other features and advantages according to the invention will be readily understood from the detailed description of the preferred embodiment in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 1 of the present invention.

Fig. 2 graphically shows various aberrations of the zoom lens system according to Example 1 in a wide-angle end state when the system is focused at infinity.

Fig. 3 graphically shows various aberrations of the zoom lens system according to Example 1 in an

intermediate focal length state when the system is focused at infinity.

Fig. 4 graphically shows various aberrations of the zoom lens system according to Example 1 in a telephoto end state when the system is focused at infinity.

Fig. 5 graphically shows various aberrations of the zoom lens system according to Example 1 in the wide-angle end state when the system is focused at the closest focusing distance.

Fig. 6 graphically shows various aberrations of the zoom lens system according to Example 1 in the intermediate focal length state when the system is focused at the closest focusing distance.

Fig. 7 graphically shows various aberrations of the zoom lens system according to Example 1 in the telephoto end state when the system is focused at the closest focusing distance.

Fig. 8 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 2 of the present invention.

Fig. 9 graphically shows various aberrations of the zoom lens system according to Example 2 in a wide-angle end state when the system is focused at infinity.

Fig. 10 graphically shows various aberrations of

the zoom lens system according to Example 2 in an intermediate focal length state when the system is focused at infinity.

Fig. 11 graphically shows various aberrations of the zoom lens system according to Example 2 in a telephoto end state when the system is focused at infinity.

Fig. 12 graphically shows various aberrations of the zoom lens system according to Example 2 in the wide-angle end state when the system is focused at the closest focusing distance.

Fig. 13 graphically shows various aberrations of the zoom lens system according to Example 2 in the intermediate focal length state when the system is focused at the closest focusing distance.

Fig. 14 graphically shows various aberrations of the zoom lens system according to Example 2 in the telephoto end state when the system is focused at the closest focusing distance.

Fig. 15 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 3 of the present invention.

Fig. 16 graphically shows various aberrations of the zoom lens system according to Example 3 in a wide-angle end state when the system is focused at infinity.

Fig. 17 graphically shows various aberrations of the zoom lens system according to Example 3 in an intermediate focal length state when the system is focused at infinity.

Fig. 18 graphically shows various aberrations of the zoom lens system according to Example 3 in a telephoto end state when the system is focused at infinity.

Fig. 19 graphically shows various aberrations of the zoom lens system according to Example 3 in the wide-angle end state when the system is focused at the closest focusing distance.

Fig. 20 graphically shows various aberrations of the zoom lens system according to Example 3 in the intermediate focal length state when the system is focused at the closest focusing distance.

Fig. 21 graphically shows various aberrations of the zoom lens system according to Example 3 in the telephoto end state when the system is focused at the closest focusing distance.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Examples of the present invention are going to be explained below with reference to accompanying drawings.

A zoom lens system according to the present invention is composed of, in order from an object, a

first lens group G1 having positive refractive power, a second lens group G2 having negative refractive power, a third lens group G3 having positive refractive power, and a fourth lens group G4 having positive refractive power. The zoom lens system is a so-called 4-group afocal zoom lens carrying out zooming by moving the second lens group G2 and the third lens group G3 along the optical axis. The first lens group G1 is composed of, in order from the object, a front lens group of the first lens group G1f having positive refractive power, a middle lens group of the first lens group G1m having negative refractive power, and a rear lens group of the first lens group G1r having positive refractive power. In the fourth lens group G4, there are three lens portions each having refractive power, which are, in order from the object, a front lens group of the fourth lens group G4f having positive refractive power, a middle lens group of the fourth lens group G4m having negative refractive power, and a rear lens group of the fourth lens group G4r having positive refractive power. The front lens group of the first lens group G1f includes two positive lens elements and a negative lens element. The middle lens group of the first lens group G1m includes a positive lens element and a negative lens element. The rear lens group of the first lens group G1r includes a positive

lens element. The lens system carries out focusing to a close object by moving the middle lens group of the first lens group G1m along the optical axis. The front lens group of the fourth lens group G4f includes a positive lens element and a negative lens element. The middle lens group of the fourth lens group G4m includes a positive lens element and two negative lens elements. The rear lens group of the fourth lens group G4r includes a positive lens element and a negative lens element. The focusing position is shifted by decentering the middle lens group of the fourth lens group G4m perpendicular to the optical axis. Thus, the large aperture internal focusing telephoto zoom lens system is constructed.

The following conditional expression (1) is preferably satisfied in order to be able to be used as a vibration reduction correction lens with keeping superb optical performance and to obtain the FNO of about 4 or less:

$$2.5 < |(F1f \times F1r234t)/(F1m \times \Phi1)| < 5.0 \qquad (1)$$

where Φ1 denotes the maximum effective diameter of the first lens group G1, F1f denotes the focal length of the front lens group of the first lens group G1f, F1m denotes the focal length of the middle lens group of the first lens group G1m, F1r234t denotes the combined focal length of the rear lens group of the first lens group G1r, the second lens group G2, the

third lens group G3, and the fourth lens group G4 in the telephoto end state.

The present invention may provide a zoom lens system having the zoom ratio of 1.7 or more, and the focal length in the telephoto end state of 300 mm or more.

When the value $|(F1f \times F1r234t)/(F1m \times \Phi1)|$ exceeds the upper limit of conditional expression (1), the diameter of the focusing lens group becomes large, so it is undesirable that fast auto focusing is difficult to be carried out. On the other hand, when the value falls below the lower limit of conditional expression (1), moving amount of the focusing group upon focusing to a close object becomes large, so it is undesirable. When the upper limit is set to 4.5, the effective diameter of the focusing group becomes relatively small, so it is desirable. When the lower limit is set to 3.0, moving amount of the focusing lens group upon focusing to a close object becomes relatively small, so it is desirable.

Moreover, the following conditional expressions (2) through (5) are preferably satisfied:

$$2.5 < |(F1f \times F4)/(F1mr23t \times \Phi1)| < 5.0 \quad (2)$$

$$2.5 < |(F1 \times F4)/(F23t \times \Phi1)| < 5.0 \quad (3)$$

$$2.5 < |(F1f \times F1r \times F4)/(F1m \times F23t \times \Phi1)| < 5.0 \quad (4)$$

$$0.7 < |(F4 \times F4m)/(F4f \times F4r)| < 1.3 \quad (5)$$

where F1 denotes the focal length of the first lens

group G1, F23t denotes the combined focal length of the second lens group G2 and the third lens group G3 in the telephoto end state, F4 denotes the focal length of the fourth lens group G4, F1r denotes the focal length of the rear lens group of the first lens group G1r, F1mr23t denotes the combined focal length of the middle lens group of the first lens group G1m, the rear lens group of the first lens group G1r, the second lens group G2 and the third lens group G3 in the telephoto end state, F4f denotes the focal length of the front lens group of the fourth lens group, F4m denotes the focal length of the middle lens group of the fourth lens group G4m, and F4r denotes the focal length of the rear lens group of the fourth lens group G4r.

When the value $|(F1f \times F4)/(F1mr23t \times \Phi 1)|$ exceeds the upper limit of conditional expression (2), variation in spherical aberration upon zooming becomes large, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (2), moving amount of the focusing lens group upon focusing to a close object becomes large, so it is undesirable. When the upper limit is set to 4.5, variation in spherical aberration upon zooming becomes small, so it is desirable. When the lower limit is set to 3.0, the moving amount of the focusing lens group upon

focusing to a close object becomes relatively small, so it is desirable.

When the value $|(F1 \times F4)/(F23t \times \Phi1)|$ exceeds the upper limit of conditional expression (3), the flatness of the image plane becomes worse, so it is not desirable. On the other hand, when the value falls below the lower limit of conditional expression (3), the total lens length of the whole lens system becomes long, so it is not desirable. When the upper limit is set to 4.5, the flatness of the image plane becomes better, so it is desirable. When the lower limit is set to 3.0, the total lens length becomes relatively shorter, so it is desirable.

When the value $|(F1f \times F1r \times F4)/(F1m \times F23t \times \Phi1)|$ exceeds the upper limit of conditional expression (4), production of spherical aberration and curvature of field becomes large, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (4), total lens length of the lens system becomes long, so it is undesirable. When the upper limit is set to 4.5, spherical aberration and curvature of field become further better, so it is desirable. When the lower limit is set to 3.0, total lens length of the lens system becomes relatively small, so it is desirable.

When the value $|(F4 \times F4m)/(F4f \times F4r)|$ exceeds the upper limit of conditional expression (5), the

flatness of the image plane upon carrying out vibration reduction correction becomes worse, it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (5), moving amount of G4m perpendicular to the optical axis, which is required for vibration reduction correction, becomes large, so it is undesirable. When the upper limit is set to 1.15, the flatness of the image plane upon carrying out vibration reduction correction becomes better, so it is desirable. When the lower limit is set to 0.85, moving amount of G4m perpendicular to the optical axis becomes further smaller, it is desirable.

Furthermore, in order to make the effective diameter of the lens system corresponding to the hand held portion as narrow as possible, it is effective that the lens system satisfies the following conditional expressions (6) through (9):

$$0.025 < |(Ft\times\Phi 4f)/(F4\times\Phi 1\times\Phi 4m)| < 0.045 \quad (6)$$

$$0.025 < |(F1\times\Phi 4f)/(F23t\times\Phi 1\times\Phi 4m)| < 0.045 \quad (7)$$

$$0.020 < |(F1f\times\Phi 1r)/(F1m\times\Phi 1\times\Phi 4m)| < 0.070 \quad (8)$$

$$0.025 < |(F1r\times\Phi 4f)/(F23t\times\Phi 1r\times\Phi 4m)| < 0.045 \quad (9)$$

where Ft denotes the focal length of the whole lens system in the telephoto end state, Φ1r denotes the maximum effective diameter of the rear lens group of the first lens group G1r, Φ4f denotes the maximum effective diameter of the front lens group of the

fourth lens group G4f, and Φ4m denotes the maximum effective diameter of the middle lens group of the fourth lens group G4m.

When the value $|(Ft\times\Phi 4f)/(F4\times\Phi 1\times\Phi 4m)|$ exceeds the upper limit of conditional expression (6), spherical aberration upon carrying out vibration reduction correction becomes worse, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (6), total lens length of the lens system becomes long, so it is undesirable. When the upper limit is set to 0.040, spherical aberration upon carrying out vibration reduction correction becomes better, so it is desirable. When the lower limit is set to 0.027, total lens length of the lens system becomes shorter, so it is desirable.

When the value $|(F1\times\Phi 4f)/(F23t\times\Phi 1\times\Phi 4m)|$ exceeds the upper limit of conditional expression (7), the flatness of the image plane becomes worse, so it is not desirable. On the other hand, when the value falls below the lower limit of conditional expression (7), total lens length of the lens system becomes long, so it is undesirable. When the upper limit is set to 0.040, the flatness of the image plane becomes better, so it is desirable. When the lower limit is set to 0.027, the total lens length becomes further shorter, so it is desirable.

When the value $|(F1f\times\Phi1r)/(F1m\times\Phi1\times\Phi4m)|$ exceeds the upper limit of conditional expression (8), total lens length of the lens system becomes long, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (8), production of spherical aberration and curvature of field becomes large, so it is undesirable. When the upper limit is set to 0.065, total lens length becomes relatively shorter, so it is desirable. When the lower limit is set to 0.026, spherical aberration and curvature of field become further better, so it is desirable.

When the value $|(F1r\times\Phi4f)/(F23t\times\Phi1r\times\Phi4m)|$ exceeds the upper limit of conditional expression (9), production of spherical aberration and curvature of field becomes large with leaving the lens construction as it is, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (9), total lens length of the lens system becomes long, so it is undesirable. When the upper limit is set to 0.040, spherical aberration and curvature of field become further better with constructing the lens system with fewer lens elements as it is, so it is desirable. When the lower limit is set to 0.027, total lens length becomes relatively shorter, so it is desirable.

In order to construct the rear lens group of the

first lens group G1r with fewer lens elements, it is effective to satisfy the following conditional expression (10):

$$0.0025 < 1/(Nd1r \times F1r) < 0.0039 \quad (10)$$

where Nd1r denotes the average refractive index of the lens elements in the rear lens group of the first lens group G1r at d-line.

When the value 1/(Nd1r×F1r) exceeds the upper limit of conditional expression (10), spherical aberration in the telephoto end state becomes large in the negative direction upon leaving the lens construction with fewer lens elements, so it is undesirable. On the other hand, when the value falls below the lower limit of conditional expression (10), total lens length of the lens system becomes long, so it is undesirable. When the upper limit is set to 0.0038, spherical aberration becomes better with constructing the lens system with fewer lens elements as it is, so it is desirable. When the lower limit is set to 0.0031, total lens length becomes relatively shorter, so it is desirable.

In order to increase portability, it is effective that the most object side lens L11 of the front lens group of the first lens group G1f is a negative meniscus lens having a convex surface facing to the object and the following conditional expression (11) is satisfied:

$$-0.0060 < 1/(NdL11 \times FL11) < -0.00050 \qquad (11)$$

where FL11 and NdL11 denote the focal length and refractive index at d-line of the negative meniscus lens, respectively.

In order to increase portability, it is effective to reduce weight of the lens system. For that purpose, when a weatherproof glass is used for the most object side lens L11, a heavy protection glass liable to be used in a so-called super telephoto lens does not become necessary. However, a lens system having the FNO of 4 or less generally has a long total lens length, so it is not suitable for this purpose. When conditional expression (11) is satisfied, optical performance and total lens length of the lens system will be both satisfactory balanced.

When the value $1/(NdL11 \times FL11)$ exceeds the upper limit of conditional expression (11), difference in the radius of curvatures of the first and second surfaces of the lens L11 tends to be null, so it becomes difficult to process the lens. On the other hand, when the value falls below the lower limit of conditional expression (11), the radius of curvature of the second surface of the lens L11 becomes small, so it is undesirable that the lens thickness becomes thick to become heavy. When the upper limit is set to -0.0010, it becomes easy to process the lens, so it is desirable. When the lower limit is set to -0.0030,

total lens length becomes further shorter, so it is desirable.

In order to obtain good optical performance upon carrying out vibration reduction correction, it is preferable that the front lens group of the fourth lens group G4f is composed of two positive lens elements and a negative lens element, and that the rear lens group of the fourth lens group G4r is composed of two positive lens elements and a negative lens element.

In order to obtain good optical property, it is preferable to arrange a field stop between the front lens group of the fourth lens group G4f and the middle lens group of the fourth lens group G4m.

Examples according to the present invention are explained below with reference to accompanying drawings.

<Example 1>

Fig. 1 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 1 of the present invention.

In Fig. 1, the zoom lens system is composed of, in order from an object, a first lens group G1 having positive refractive power, a second lens group G2 having negative refractive power, a third lens group G3 having positive refractive power, and a fourth

lens group G4 having positive refractive power. Zooming is carried out by moving the second lens group G2 and the third lens group G3 along the optical axis. In the fourth lens group G4, there are three lens portions with refractive power that are, in order from the object, a front lens group of the fourth lens group G4f having positive refractive power, a middle lens group of the fourth lens group G4m having negative refractive power, and a rear lens group of the fourth lens group G4r having positive refractive power. Vibration reduction correction is carried out by changing the focusing position with shifting the middle lens group of the fourth lens group G4m perpendicular to the optical axis.

The first lens group G1 having positive refractive power is composed of a front lens group of the first lens group G1f fixed along the optical axis relative to an image plane I, a middle lens group of the first lens group G1m movable along the optical axis, and a rear lens group of the first lens group G1r fixed along the optical axis relative to the image plane. Focusing to a close object is carried out by moving the middle lens group of the first lens group G1m along the optical axis.

As for each lens element, the front lens group of the first lens group G1f is composed of, in order from the object, a cemented positive lens constructed

by a negative meniscus lens L11 having a convex surface facing to the object cemented with a double convex lens L12, a positive meniscus lens L13 having a convex surface facing to the object, and a positive meniscus lens L14 having a convex surface facing to the object. The middle lens group of the first lens group G1m is composed of, in order from the object, a double concave lens L15, and a cemented negative lens constructed by a positive meniscus lens L16 having a convex surface facing to an image cemented with a double concave lens L17. The rear lens group of the first lens group G1r is composed of a positive meniscus lens L18 having a convex surface facing to the image. The second lens group G2 is composed of, in order from the object, a negative lens L21 having a stronger concave surface facing to the image, a cemented negative lens constructed by a double convex lens L22 cemented with a double concave lens L23, and a negative meniscus lens L24 having a stronger concave surface facing to the object. The third lens group G3 is composed of, in order from the object, a double convex lens L31, and a cemented positive lens constructed by a positive lens L32 having a gentle radius of curvature facing to the object cemented with a negative meniscus lens L33 having a concave surface facing to the object. Next to the third lens group G3, there is an aperture stop S1. The front

lens group of the fourth lens group G4f is composed of, in order from the object, a cemented positive lens constructed by a negative meniscus lens L41 having a convex surface facing to the object cemented with a double convex lens L42, and a positive meniscus lens L43 having a convex surface facing to the object. There is a field stop S2 apart from the front lens group of the fourth lens group G4f with a wide space. The middle lens group of the fourth lens group G4m is composed of, in order from the object, a cemented negative lens constructed by a double convex lens L44 cemented with a double concave lens L45, and a double concave lens L46. The rear lens group of the fourth lens group G4r is composed of, in order from the object, a double convex lens L47, and a cemented positive lens constructed by a double convex lens L48 cemented with a double concave lens L49. The fourth lens group G4 further includes a rear-inserting filter BFL. Thus the large aperture internal focusing telephoto zoom lens according to Example 1 is constructed.

Various values associated with Example 1 are listed in Table 1. In Table 1, F denotes the focal length of the zoom lens system, FNO denotes the f-number, β denotes the imaging magnification, BF denotes back focal length, D0 denotes the distance between an object and the object side surface of the

lens L11 in the first lens group G1. I denotes the image plane. The number in the left side column denotes surface number in order from the object, r denotes radius of curvature of each lens surface, d denotes a distance along the optical axis between adjacent lens surfaces, nd denotes refractive index of a medium between adjacent lens surfaces at d-line (λ=587.6nm), ν denotes Abbe number of a medium between adjacent lens surfaces, and refractive index of the air 1.00000 is omitted. Φ1 denotes the maximum effective diameter of the first lens group G1, Φ1r denotes the maximum effective diameter of the rear lens group of the first lens group G1r, Φ4f denotes the maximum effective diameter of the front lens group of the fourth lens group G4f, Φ4m denotes the maximum effective diameter of the middle lens group of the fourth lens group G4m. Radius curvature 0.0000 means a flat plane.

In the tables for various values, "mm" is generally used for the unit of length such as the focal length, the radius of curvature, and the separation between lens surfaces. However, since an optical system proportionally enlarged or reduced its dimension can be obtained similar optical performance, the unit is not necessary to be limited to "mm" and any other suitable unit can be used.

The above-mentioned explanation can be applied

to any other Examples in the present invention.

Table 1

(Specifications)

F: 204.0 392.00 mm

FNO: 4.08

(Lens Data)

	r	d	ν	nd	Φ
1)	370.787	5.30	33.89	1.80384	Φ1f=102.10
2)	127.285	16.00	82.56	1.49782	
3)	-684.010	0.20			
4)	141.046	9.50	82.56	1.49782	
5)	729.910	0.20			
6)	158.558	9.50	82.56	1.49782	
7)	3054.000	(d7)			
8)	-294.108	2.90	47.38	1.78800	
9)	141.046	9.00			
10)	-452.783	4.00	23.78	1.84666	
11)	-194.473	2.90	65.47	1.60300	
12)	308.660	(d12)			
13)	-674.360	5.40	39.59	1.80440	
14)	-113.025	(d14)			Φ1r=55.86
15)	699.210	1.90	55.52	1.69680	
16)	80.551	2.05			

17)	749.830	4.50	23.78	1.84666	
18)	-81.072	1.90	60.09	1.64000	
19)	148.037	3.94			
20)	-61.497	1.90	60.09	1.64000	
21)	-661.360	(d21)			
22)	349.981	3.50	65.47	1.60300	
23)	-349.981	0.50			
24)	623.770	6.00	65.47	1.60300	
25)	-52.992	1.90	28.55	1.79504	
26)	-104.522	(d26)			
27>	0.000	1.00			Aperture Stop S1
28)	119.718	2.00	33.89	1.80384	Φ4f=38.49
29)	81.535	4.50	65.47	1.60300	
30)	-848.550	0.10			
31)	68.648	4.00	65.47	1.60300	
32)	159.707	22.00			
33)	0.000	2.27			Field Stop S2
34)	440.216	3.30	23.78	1.84666	Φ4m=27.83
35)	-72.192	1.60	52.67	1.74100	
36)	57.121	4.50			
37)	-462.274	1.60	52.67	1.74100	
38)	110.561	4.86			
39)	286.107	4.00	82.56	1.49782	
40)	-91.116	0.10			
41)	64.829	6.50	60.09	1.64000	

42)	-64.829	1.70	23.78	1.84666
43)	417.363	3.00		
44)	0.000	2.00	64.12	1.51680
45)	0.000	Bf		

(Variable distance upon focusing and zooming)

	Wide-angle	Middle	Telephoto
<Focused at infinity>			
F	204.0000	300.0000	392.0000
D0	∞	∞	∞
d7	54.90581	54.90581	54.90581
d12	23.85167	23.85167	23.85167
d14	5.84488	38.59130	54.82963
d21	29.27185	15.53993	2.41844
Bf	91.16781	91.16781	91.16781
<Focused at closest distance>			
β	-0.13941	-0.20502	-0.26789
D0	1607.6776	1607.6776	1607.6776
d7	72.39989	72.39989	72.39989
d12	6.35759	6.35759	6.35759
d14	5.84488	38.59130	54.82963
d21	29.27185	15.53993	2.41844
d26	25.24955	6.23504	3.11820
Bf	91.16781	91.16781	91.16781

(Moving Amount for Vibration reduction correction)

<Focused at infinity>			
F	204.0000	300.0000	392.0000
G4m	1.000	1.000	1.000

I(Image Plane)	-1.828	-1.828	-1.828
<Focused at closest distance>			
β	-0.13941	-0.20502	-0.26789
G4m	1.000	1.000	1.000
I(Image Plane)	-1.828	-1.828	-1.828

Figs. 2, 3, 4 graphically show various aberrations of the zoom lens system according to Example 1 in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at infinity. Figs. 5, 6, 7 graphically show various aberrations of the zoom lens system in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at the closest focusing distance (R=2000mm). In respective graphs, Y denotes an image height, FNO denotes the f-number, D denotes d-line (λ=587.6nm), G denotes g-line (λ=435.6nm), C denotes C-line (λ=656.3nm), and F denotes F-line (λ=486.1nm). In the graphs showing spherical aberration, f-number according to the maximum aperture or the maximum NA value is shown. In the graphs showing astigmatism or distortion, the value of the maximum image height Y is shown. In the graphs showing coma, the value of each image height Y is shown. In the graphs showing astigmatism, a solid line indicates a sagittal image

plane, and a broken line indicates a meridional image plane. In all aberration graphs of the following examples, the same denotations are applied.

Values for conditional expressions are listed all together in Table 4 at the end of Example 3.

As is apparent from the respective graphs showing various aberrations, excellent compensation is made for various aberrations upon operating vibration reduction correction as well as common use.

<Example 2>

Fig. 8 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 2 of the present invention in a wide-angle end state focusing at infinity. Construction of each lens group is the same as that of Example 1, so duplicated explanation is avoided.

Various values associated with Example 2 of the present invention are listed in Table 2.

Table 2

(Specifications)

F: 204.00 392.00 mm

FNO: 4.08

(Lens Data)

	r	d	ν	nd	Φ
1)	307.3433	5.30	33.89	1.80384	Φ1f=98.00

2)	105.1555	17.00	82.56	1.49782	
3)	-597.7919	0.20			
4)	123.4141	11.00	82.56	1.49782	
5)	2021.0593	0.20			
6)	139.0111	9.50	82.56	1.49782	
7)	5459.3449	(d7)			
8)	-312.9890	2.90	47.38	1.78800	
9)	129.3204	9.00			
10)	-521.7640	4.00	23.78	1.84666	
11)	-183.5824	2.90	65.47	1.60300	
12)	309.1483	(d12)			
13)	-572.7124	6.00	39.59	1.80440	
14)	-109.8916	(d14)			Φ1r=61.73
15)	-37746.8820	1.90	55.52	1.69680	
16)	78.6678	3.00			
17)	886.9739	4.50	23.78	1.84666	
18)	-81.1191	1.90	60.09	1.64000	
19)	148.3783	5.00			
20)	-60.7376	1.90	60.09	1.64000	
21)	-242.9932	(d21)			
22)	232.1951	3.50	65.47	1.60300	
23)	-232.1951	0.50			
24)	-558.3594	6.00	65.47	1.60300	

25)	-60.4971	1.90	28.55	1.79504	
26)	-125.7892	(d26)			
27>	0.0000	1.00			Aperture Stop S1
28)	116.7579	2.00	33.89	1.80384	$\Phi 4f = 43.29$
29)	94.2184	4.50	65.47	1.60300	
30)	-1221.5662	0.10			
31)	72.2443	4.00	65.47	1.60300	
32)	139.6178	22.00			
33)	0.0000	1.75			Field Stop S2
34)	440.2160	3.30	23.78	1.84666	$\Phi 4m = 31.80$
35)	-72.1920	1.60	52.67	1.74100	
36)	57.1210	4.50			
37)	-462.2740	1.60	52.67	1.74100	
38)	110.5610	4.75			
39)	297.0630	4.00	82.56	1.49782	
40)	-93.6283	0.10			
41)	64.9661	6.50	60.09	1.64000	
42)	-64.9661	1.70	23.78	1.84666	
43)	475.7340	3.00			
44)	0.0000	2.00	64.12	1.51680	
45)	0.0000	Bf			

(Variable distance upon focusing and zooming)

	Wide-angle	Middle	Telephoto
<Focused at infinity>			
F	204.0000	300.0000	392.0000
D0	∞	∞	∞

d7	33.09192	33.09192	33.09192
d12	23.06833	23.06833	23.06833
d14	6.34150	30.23978	42.06173
d21	38.90070	20.18608	2.38896
d26	9.86848	4.68483	10.66000
Bf	106.23003	106.23003	106.23003

<Focused at closest distance>

β	-0.13418	-0.19732	-0.25783
DO	1615.9983	1615.9983	1615.9983
d7	44.4275	44.4275	44.4275
d12	11.73272	11.73272	11.73272
d14	6.34150	30.23978	42.06173
d21	38.90070	20.18608	2.38896
d26	9.86848	4.68483	10.66000
Bf	106.23003	106.23003	106.23003

(Moving Amount for Vibration reduction correction)

<Focused at infinity>

F	204.0000	300.0000	392.0000
G4m	1.000	1.000	1.000
I(Image Plane)	-2.074	-2.074	-2.074

<Focused at closest distance>

β	-0.13418	-0.19732	-0.25783
G4m	1.000	1.000	1.000
I(Image Plane)	-2.074	-2.074	-2.074

Figs. 9, 10, 11 graphically show various aberrations of the zoom lens system according to

Example 2 in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at infinity. Figs. 12, 13, 14 graphically show various aberrations of the zoom lens system in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at the closest focusing distance (R=2000mm).

As is apparent from the respective graphs showing various aberrations, excellent compensation is made for various aberrations upon operating vibration reduction correction as well as common use.

<Example 3>

Fig. 15 is a diagram showing the lens arrangement of a large aperture internal focusing telephoto zoom lens system according to Example 3 of the present invention in the wide-angle end state focusing at infinity. Construction of each lens group is the same as that of Example 1, so duplicated explanation is avoided.

Various values associated with Example 3 of the present invention are listed in Table 3.

Table 3

(Specifications)

F: 204.00 392.00 mm

FNO: 4.08

(Lens Data)

	r	d	ν	nd	Φ
1)	0.0000	4.00	64.12	1.51680	
2)	0.0000	1.20			
3)	374.1092	5.30	33.89	1.80384	Φ1f=126.00
4)	154.7822	19.00	82.56	1.49782	
5)	-821.8595	0.20			
6)	158.3504	11.50	82.56	1.49782	
7)	579.5842	0.20			
8)	194.6656	11.00	82.56	1.49782	
9)	1705.8611	(d9)			
10)	-303.7329	2.90	47.38	1.78800	
11)	144.5685	9.00			
12)	-316.2813	4.00	23.78	1.84666	
13)	-206.3012	2.90	65.47	1.60300	
14)	461.6225	(d14)			
15)	-1259.1676	5.40	43.35	1.84042	
16)	-127.2577	(d16)			Φ1r=53.53
17)	-401.4289	1.90	55.52	1.69680	
18)	134.8197	2.05			
19)	662.6791	4.50	23.78	1.84666	
20)	-77.1176	1.90	60.09	1.64000	
21)	87.7254	3.94			

22)	-60.1053	1.90	60.09	1.64000	
23)	-205.3204	(d23)			
24)	345.5976	3.50	65.47	1.60300	
25)	-345.5976	0.50			
26)	971.0425	6.00	65.47	1.60300	
27)	-45.2978	1.90	28.55	1.79504	
28)	-87.2469	(d28)			
29>	0.0000	1.00			Aperture Stop S1
30)	118.1376	2.00	33.89	1.80384	Φ4f=37.55
31)	73.2281	4.50	65.47	1.60300	
32)	-646.0891	0.10			
33)	65.4667	4.00	65.47	1.60300	
34)	159.6390	22.00			
35)	0.0000	2.44			Field Stop S2
36)	440.2160	3.30	23.78	1.84666	Φ4m=26.96
37)	-72.1920	1.60	52.67	1.74100	
38)	57.1210	4.50			
39)	-462.2740	1.60	52.67	1.74100	
40)	110.5610	4.66			
41)	302.8573	4.00	82.56	1.49782	
42)	-90.4568	0.10			
43)	67.4726	6.50	60.09	1.64000	
44)	-67.4726	1.70	23.78	1.84666	
45)	508.2043	3.00			
46)	0.0000	2.00	64.12	1.51680	

47) 0.0000 Bf

(Variable distance upon focusing and zooming)

	Wide-angle	Middle	Telephoto
<Focusing at infinity>			
F	204.0000	300.0000	392.0000
D0	∞	∞	∞
d9	72.98056	72.98056	72.98056
d14	28.12323	28.12323	28.12323
d16	6.67272	48.23853	69.05568
d23	24.24142	13.66375	3.51157
d28	44.83193	13.84380	3.17881
Bf	85.01905	85.01904	85.01906
<Focusing at closest distance>			
β	-0.15011	-0.22075	-0.28845
D0	1564.4436	1564.4436	1564.4436
d9	99.07534	99.07534	99.07534
d14	2.02845	2.02845	2.02845
d16	6.67272	48.23853	69.05568
d23	24.24142	13.66375	3.51157
d28	44.83193	13.84380	3.17881
Bf	85.01905	85.01905	85.01907

(Moving Amount for Vibration reduction correction)

<Focusing at infinity>			
F	204.0000	300.0000	392.0000
G4m	1.000	1.000	1.000
I(Image Plane)	-1.724	-1.724	-1.724

<Focusing at closest distance>

β	-0.15011	-0.22075	-0.28845
G4m	1.000	1.000	1.000
I(Image Plane)	-1.724	-1.724	-1.724

Figs. 16, 17, 18 graphically show various aberrations of the zoom lens system according to Example 3 in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at infinity. Figs. 19, 20, 21 graphically show various aberrations of the zoom lens system in the wide-angle end state, the intermediate focal length state, and the telephoto end state, respectively, when the system is focused at the closest focusing distance (R=2000mm).

As is apparent from the respective graphs showing various aberrations, excellent compensation is made for various aberrations upon operating vibration reduction correction as well as common use.

By the way, a plane parallel grass FFL for protection may be placed to the object side of the lens element L11 as shown in Example 3.

Values for conditional expressions are listed all together in Table 4.

Table 4

	Example	Example	Example

	1	2	3
(1): $\lvert (F1f \times F1r234t)/(F1m \times \Phi 1) \rvert$	3.491	4.618	3.127
(2): $\lvert (F1f \times F4)/(F1mr23t \times \Phi 1) \rvert$	3.853	4.050	3.112
(3): $\lvert (F1 \times F4)/(F23t \times \Phi 1) \rvert$	3.844	4.035	3.117
(4): $\lvert (F1f \times F1r \times F4)/(F1m \times F23t \times \Phi 1) \rvert$	3.844	3.745	3.005
(5): $\lvert (F4 \times F4m)/(F4f \times F4r) \rvert$	1.066	1.120	1.036
(6): $\lvert (Ft \times \Phi 4f)/(F4 \times \Phi 1 \times \Phi 4m) \rvert$	0.031	0.029	0.028
(7): $\lvert (F1 \times \Phi 4f)/(F23t \times \Phi 1 \times \Phi 4m) \rvert$	0.031	0.029	0.028
(8): $\lvert (F1f \times \Phi 1r)/(F1m \times \Phi 1 \times \Phi 4m) \rvert$	0.033	0.027	0.063
(9): $\lvert (F1r \times \Phi 4f)/(F23t \times \Phi 1r \times \Phi 4m) \rvert$	0.032	0.029	0.030
(10): $1/(Nd1r \times F1r)$	0.0033	0.0037	0.0032
(11): $1/(NdL11 \times FL11)$	-0.0023	-0.0028	-0.0017

As described above the present invention makes it possible to provide a large aperture internal focusing telephoto zoom lens system having the FNO of about 4 or less capable of being used as a vibration reduction correction lens with keeping superior optical performance.

Moreover, the present invention makes it possible to provide a large aperture, internal focusing, telephoto zoom lens system having the focal length in the telephoto end state of 300mm or more, and the zoom ratio of 1.7 or more, making the effective diameter of the lens system corresponding to the hand held portion as narrow as possible for keeping good portability.

Furthermore, in the present invention, since focusing lens group, zooming lens group, and vibration reduction correction lens group are independent with each other, mechanical construction can be relatively simple, so that it is easy to make the structure tolerant of vibration or an impact of a fall. Here, if you do not mind that the outer diameter of the lens barrel becomes large, it is possible to carry out vibration reduction correction with the front lens group of the fourth lens group. In Examples 1 and 2 also, a filter may be applied to the object side of the most object side lens of the front lens group of the first lens group.

Additional advantages and modification will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, and representative devices shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.